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ABSTRACT

The national need for an ample pool of research scientists is considered. Research in universities and in the federally funded research facilities is described, and the importance of the research these institutions do and the interweaving of research and instruction in universities are noted. Some manpower projections are included and questions are posed about the prospects for universities and the facilities, about their ability to make more appointments on their staffs, to divide responsibilities in research, and to work together. Thirteen questions are submitted for discussion and resolution by the government and the universities, and by other concerned groups. The discussion of this topic is based on a literature review and meetings with selected officials from business, government, and the universities. Appended materials include a list of federally funded research and development centers administered by universities, a list of information sources, and a bibliography.
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RESEARCH PERSONNEL:

An Essay on Policy

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NATIONAL COMMISSION ON RESEARCH

Research Personnel: An Essay on Policy

Executive Summary

This fifth and final report of the National Commission on Research is an essay about the national need for an ample pool of research scientists.

The Commission finds that even the most careful manpower projections are too narrow and unconfident to be a sound basis for planning. Instead, the Commission placed its confidence in the quality and cooperation of our different kinds of research institutions. The essay therefore describes research in universities and in the federally funded research facilities; it also notes the kinds and the importance of the research these institutions do and the interweaving of research and instruction in universities. The Commission believes that the facilities are increasingly important in the advance of research, and that new relationships will have to be established between the facilities and the universities.

The essay concludes with questions about the prospects for universities and the facilities, about their ability to make more appointments on their staffs, to divide responsibilities in research, and to work together in renewing our national resources for research and in providing a supply system for its conduct. Thirteen questions are submitted for discussion and resolution by the government and the universities, and by other groups concerned with the quality of future research:

1. Are the universities, is the government (as having a general interest in science) satisfied with the ways in which young people are introduced to science in the elementary and secondary schools? If they are dissatisfied, what is their dissatisfaction, and what do they propose to do about it?
2. Are the universities satisfied with the ways in which college students are introduced to science, the students who will major in science, and also those who are not looking forward to scientific careers? Since broad public attitudes, whatever their understanding or misunderstanding, have their basis partly in our educations, if the universities are dissatisfied with those attitudes and with the introductions which they provide for their students, what improvements do they propose to make?
3. Are the universities, is the government, and are the facilities concerned about the numbers of well prepared scientists we will need at the start of the next century? Are they sure that they will have or can create places for the numbers of scientists we will need?
4. Are the universities and the facilities satisfied that they have devised effective means to assure access to scientific careers for persons from all sectors of society, including minorities, handicapped, and women? Is the government satisfied that it applies appropriate and effective mechanisms to enforce Constitutional and statutory rights for equal opportunity? Is society satisfied with government performance in these responsibilities? Are these access and equality questions based on a suitable understanding of the roles and responsibilities of governmental and academic institutions and of individuals?
5. Are the universities satisfied, is the government satisfied, that it is good for universities to undertake very large organized research projects which employ non-faculty scientists and which require faculty members to reduce their instruction and research and to serve as research managers?
6. What measures can the universities and the federal facilities make to improve the research which they sponsor and conduct? What, if anything, can they do to improve the effectiveness of their research faculties and staffs, the circumstances under which their research is conducted, the procedures by which their research is administered, and the understandings their constituents have of their instructional and research programs?
7. Are the universities and the government satisfied that a judicious division has been made between the research which is properly conducted in the universities and the research which is suitable to facilities? Are there discussions between them about the division of research, about the needs for further facilities, about their most appropriate location and administration, and about the duration and paces of the research programs they sponsor and conduct?

8. Are the universities settled that the universities shall provide the whole formal education of the persons who intend to make careers in research, or are they open to experiment? Have the universities and the government considered the consequences of offering advanced instruction in some fields in federally funded research facilities, and perhaps even having the facilities become the formal authorities for the award of the Ph.D. degree? Are all other institutions satisfied with the principle that instruction shall be provided by university faculties even while advanced research by some students is conducted in government facilities?
9. Are the universities and the government satisfied that they have done all they can to assure that the laboratories of their scientists are well equipped?
10. Are the universities and is the government satisfied that their procedures for administering research are as unobtrusive and non-interfering as possible?
11. Have the universities and the government given attentive thought to the changes which occur in the research lives of the scientists and to their effects on their morale and productivity?
12. Are the universities and the government satisfied that they have devised effective means of making accessible to industry and to the public at large the results of the research they sponsor?
13. Is the government, and are the universities and industry satisfied that they understand their mutual interest in having excellent research conducted, and are they satisfied that they cooperate suitably in defining, supporting, and conducting research?

RESEARCH PERSONNEL:
An Essay on Policy

National Commission on Research
August 1980

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Foreword

The National Commission on Research is a private, nonprofit organization established to examine the relationships between government agencies and universities involved in research and to develop specific recommendations for improvements. The Commission was founded in the latter half of 1978 by the American Council on Education, the American Council of Learned Societies, the Association of American Universities, the National Academy of Sciences, the National Association of State Universities and Land-Grant Colleges, and the Social Science Research Council. The Commission works independently of its founders to examine the process by which the Federal government supports academic research and to propose changes designed to improve that process.

Funding has been obtained for Commission activities to pursue this task from the following organizations: Carnegie Corporation of New York, Exxon Education Foundation, Ford Foundation, the William and Flora Hewlett Foundation, the Andrew W. Mellon Foundation, the National Science Foundation (Grants Nos. PRM-7903778 and CDP-7926386), the U.S. Department of Energy (Grant No. DE-FG01-80ER10167), and the Air Force Office of Scientific Research (Grant No. AFOSR-ISSA-80-00030). Over three-fourths of the funding was made available by the five private agencies and approximately one-fourth from the public sources. Any opinions, findings, conclusions, and recommendations expressed in this publication are the sole responsibility of the Commission and do not necessarily reflect the views of any of the aforementioned funding sources or founders.

The Commission has published a series of reports analyzing the process of government funding and university involvement in research and making recommendations to all affected parties for improvements in the system. Subcommittees of the Commission have investigated each of the following issues:

- (1) Accountability;
- (2) Peer review and other selection processes;
- (3) Alternate funding mechanisms;
- (4) Industry/university/government relationships; and
- (5) Development of research personnel.

The character of this paper on research personnel is unlike the other reports. Its essay style is intended to raise issues for discussion, not to make recommendations for action by specific persons or groups.

The members of the Subcommittee on Research Personnel were Irwin C. Lieb, Chairman; Philip P. Cohen; Dale R. Corson; Donald N. Langenberg; Charles A. Mosher; and Linda S. Wilson.

In addition to surveying the available literature, subcommittee members and staff met with selected officials from business, government, and the universities. At monthly meetings, invited speakers presented their views on pertinent aspects of the listed topics or on the broad purview of the Commission. The Commission received testimony on five university campuses from faculty members and administrators, as well as written comments stemming from invitations to research universities and from an open letter in *Science* magazine. Liaison with numerous government agencies was maintained through telephone contacts, correspondence, and attendance at Commission meetings. Approximately one hundred fifty persons gave advice and information to assist the Commission in its study. The Commission appreciated the efforts of all the participants in its deliberations and discussions. A description of these considerations and a partial list of individuals are contained in the Appendix.

The members of the Commission are listed inside the front cover. These individuals have backgrounds in education, business, and government. They accepted appointments to serve on the Commission without compensation. During Commission deliberations, they reflected their own experience and not necessarily the viewpoints of their institutions or organizations.

Liaison persons were designated to the Commission by the following government agencies: Alcohol, Drug Abuse, and Mental Health Administration (ADAMHA); Department of Defense (DOD); Department of Energy (DOE); Department of Health, Education, and Welfare (DHEW)*; General Accounting Office (GAO); National Aeronautics and Space Administration (NASA); National Institutes of Health (NIH); National Science Foundation (NSF); Office of Management and Budget (OMB); and Office of Science and Technology Policy (OSTP).

*No new liaison persons were designated after the Department of Health, Education, and Welfare became the Department of Health and Human Services and with the inception of the Department of Education.

In its series of publications, the Commission has reviewed the key elements of the present state of federally supported university research, affirmed what it believed to be good in this system, analyzed problem areas, and provided suggestions for actions to alleviate these problems. The Commission recognized that much diversity exists in the complex relationships among principal investigators, research administrators, and others in the university community, and program officers, auditors, administrators, and other government personnel. There is a wide range of beneficiaries, including industry, students, and the general public. The goals of the participating government organizations and educational institutions and of the concerned individuals involved in federally supported research are diverse and sometimes overlapping but not identical. Therefore, the Commission did not anticipate the ability to establish consensus on all of the issues. The Commission did seek to make a contribution to improved research in our nation by improving a system which produces a major portion of that research.

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Introduction

This fifth and final report of the National Commission on Research is about the nation's need for an ample pool of research scientists. It is an essay about basic research, about quality in research, and about the institutions in which scientists are educated and research is conducted. The intent of the essay is to raise issues. It, therefore, does not conclude with recommendations, as our other reports have done. It ends with questions instead, questions which the Commission thinks express the apprehensions so many persons now feel about the prospects for research, and which also formulate issues about instruction and research policy which the universities and the government have to discuss and resolve.

The Commission has chosen an essay form of exposition because it wants to invite discussion of the policies within which specific recommendations should be assessed. It believes that the emphasis, the supposition, and the focus of even the most careful manpower projections are arguable and should have critical review. It also is not convinced that the "right solution" for personnel problems is to be found in proposals about preparing and employing definite numbers of persons, but in seeing to the quality and cooperation of our different kinds of research institutions. Issues of their quality and cooperation should be the basis for recommendations and they should be carefully explored.

Four notes about scientific manpower projections are especially important:

First, the projections, as we will see, have to do with the numbers of students who will be entering the colleges and universities in the next twenty years, the number of faculty who will retire within that time, and the number of new faculty who are likely to be appointed. All these numbers have to be adjusted to take account of the current shifts of students away from the arts and sciences into professional preparations, the competition between industry and universities for decreased numbers of research graduates, and the programs designed to encourage early faculty retirements. When the numbers are adjusted, they become still more tentative and even more uncertain as a basis for prediction and planning.

Second, the projections, in their emphasis on numbers, leave aside issues about the quality of both the persons who are now engaged in research and those who are preparing for research careers. There is no good equation between quality and quantity. We do not know whether two or four very able scientists are as good as ten competent ones. Whatever the measure, accent should clearly be placed on quality. The question then is how quality is assured.

Third, the projections focus on universities. They do not mention the already large and still growing number of federally funded research facilities in which major advanced research is being done. They, therefore, neglect issues about the associations between the universities and the facilities, though these bear on both the provision of instruction and the conduct of research.

Finally, in most of the projections, however carefully their numbers are adjusted, there is a critical supposition. It is that the numbers direct us to recommendations because *everything else will remain the same*—that the universities, for example, will continue to conduct themselves and their research as they do now, and that the agencies, instruments, mechanisms, and amounts of federal support will continue otherwise unchanged. The Commission believes, on the contrary, that *not everything else will remain the same*, indeed that the changes which are now occurring are significant and are part of the cause of our apprehensions about the future of the nation's science.

The Commission is wary of specific manpower projections, then, because when attempts are made to adjust the numbers on which they are based, the basis they provide for the projections is unconfident. The assumption that everything else will remain the same is also precarious.

In the last thirty years, there have been many changes in the ways universities authorize and provide for the conduct of research. For all their stability and tradition, universities are one of the most flexible and accommodating of our institutions. There is no strong reason to think that in the years ahead there will not be major changes in them, undertaken out of their own initiatives, or in response to changing political, social, or industrial requirements for research. There are also likely to be changes in other of the organizations which conduct research, in government laboratories and facilities, for example, and in industrial research organizations.

The possibility of such changes should be considered. Until account is taken of the broad bearing of possible changes on the conduct of research, the Commission's attitude toward manpower projections is cautious. Our firmest confidence is in the quality, variety, and flexibility of our institutions for research. If they are good, if the institutions are administered well, and if the associations between them are good, we are likely better to see what each sort of institution can do, how functions performed by one might be partly shared or shifted to others, and how the system of our institutions might accommodate itself to changes in our research requirements.

What the Commission, therefore, intends to do is to look first and briefly at the projections of personnel and then, at greater length, at the institutions in which basic research is conducted. We will consider what their other missions are; how their research is generated and under what auspices and with what expectations it is conducted; how and at what rate and in what ways they can be made to accommodate more or less research, and what they can do or have done for them which will improve the quality of the research they conduct.

The Commission supposes that, in the years ahead, the amount of research which will be done will continue to be large. Its principal concern then is not with changes of scale but with the quality of research, with its being basic and incisive, and capable of extension and refinement both in and beyond the fields in which it originates, and with its being applicable as well. Since the Commission's charter is to look to the relationships between the Federal government and the universities, these will be the central figures in our discussion. Industry, though an important performer of basic research, does not directly contribute to the renewal of our pool of research personnel and, therefore, will not be given emphasis.

Manpower Projections: Problems of Personnel

There will be fewer eighteen-year olds entering the colleges in the next fifteen years and far fewer students entering the graduate schools in engineering and the arts and sciences. The number of undergraduate students will be about the same as it was ten years ago. College and university faculties will decrease in size, and faculties on the average will become older, because many retiring faculty will not be replaced and the mandated later retirement age will enable current faculties to teach for a longer time. Because of the decreasing size and increasing age of the faculty, fewer young people will be appointed to college and university positions. The figures for student enrollments and faculty retirements are firm. When they are adjusted to take account of the shifts of students from the arts and sciences fields to undergraduate and graduate professional preparations, and when universities consider how they have to compete with business and industry for a smaller number of research graduates, the prospects for the size and quality of the faculties in engineering and in the arts and sciences is unsettling. For the next fifteen to twenty years, the projected numbers and adjustment show three aspects:

First, there will be fewer graduate students in engineering and the arts and sciences; and, there will also be questions about their comparative quality.

Second, there will be fewer opportunities for faculty appointments in research universities.

Third, universities will find compelling competition from business and industry for the fewer new Ph.D.s.

The portent of these conditions is that we may not be able to prepare enough scientists and scholars to meet the requirements for teachers at the start of a new century, that there will be fewer new researchers in the universities, and that the quality of American science and scholarship may be diminished if there are fewer contributions made to them through university research.

These prospects seem especially grave in the sciences and engineering where, for other reasons as well, there has been growing apprehension that American science and technology will not continue to be as forward as they have been. The apprehension is not about the quality of science alone. It is also about the fact that basic science often leads to innovation in technology. In turn, these affect the productivity of the nation's industry, the stability and growth of our economy and commerce, our political and military strength and standing, and the options available for our diplomacy. Basic research has large economic, social, and political consequences—and the apprehension over the quality of future American science has resonance with other concerns which have been taken as a token of the decline in American power.

It is because of the large consequence of science that the Federal government has provided major support for basic research in universities, especially since Sputnik, in 1957. The government policy has not been to support universities. It has been massively to support research, and the government has supported research in the universities because it was only in universities that there could then be found the numbers of able scientists who could conduct basic research on so large a projected scale. Even now, though government laboratory and facility research have grown enormously, about sixty percent of the federal funds expended for basic research are spent in universities. When the funds which universities themselves invest in basic research are added to these figures, the proportion of funds spent in universities for basic research to the total funding for research is very high.

The figures about declining enrollments, about fewer appointments to university faculties and fewer students preparing for research careers are cause for concern about the prospects for the quality and quantity of basic research in the universities. Because most of our basic research is done in universities, the figures are also cause for apprehension about the general prospects for science in our country. We have no exact measures for the apprehension. But many persons, in universities, the government, the foundations, industry, and in the popular press, have begun to formulate the problems and to consider how they might be solved.

The problems seem posed initially by the numbers—by the number of students who will enter the colleges and graduate schools and by the number of faculty appointments which will be made in years ahead. The problems then seem to be how to change the numbers, or their direction, rate, slope, or some other dimension of them, and to decide who can make the changes which will make the portent of the numbers less severe. Most of those who reflect on the numbers think that the government can and should do something to change them. The government is the major supporter of basic research; it represents the nation's interest in having research done, and it is thought to have the resources which are needed to make the changes.

Many committees and commissions have, therefore, recommended to the government that there be more government funded graduate and post-doctoral fellowships, that there be government supported faculty appointments, that government funds be provided to change the rate at which new appointments are made, and that more funds be appropriated for equipment and for research.

The National Commission on Research does not oppose these recommendations. All of them would be of use; all are feasible. But neither does the Commission strongly urge that they be supported. The question whether they should be supported depends on broad issues of educational and research policy, and these have not been discussed widely and critically enough. The Commission, therefore, thinks that it would be premature or perhaps not sufficiently effective to enact one or another of the specific manpower proposals. A recommendation for them should be a part of a comprehensive policy. Our own discussion of the issues in such a policy begins with a review of research in the universities.

Research Universities

Brief History

American universities have sponsored basic research and experimental science for only a little more than one hundred years. For most of the 19th Century, universities were devoted to professional preparations. They thought of experiment as either tinkering or as part of technology and, in either case, not appropriate for study in a university.

Many scientists also opposed the idea of conducting research in universities. They felt that universities would not give scientists positions of dignity, would not give high standing to research, and would not support it suitably. They also thought that the responsibilities of instruction would leave them too little time for research.

Both sides began to change their attitudes after the Morrill Act was passed, after the Civil War, when there were new needs for more organized technologies; and in the late 1800s, universities began to formalize graduate study and research in official university programs.

At the present time, the major universities are research universities. There are few if any remnants in them of the older opposition between experimental science and professional preparation. Research is a large and regular portion of graduate instruction, and its conduct in universities has important effects on the currency and vitality of undergraduate instruction.

Many university faculty members in the sciences are occupied almost entirely with graduate education and research. Their appointments and promotions are based largely on their promise and achievement in research; these are measured partly by their success in securing research grants. Funds from grants provide stipends for graduate students who are research assistants, for equipment, supplies, and other research expenses, and often for a portion of a research professor's salary. Graduate study, especially in the sciences, is almost inextricably connected with research, in theory as well as fact.

Instruction and Research

The interweaving of instruction and research in science in American universities is a distinctive contribution to educational theory and practice. In many other countries, the two are more distinct, or they were until very recently. It was common, for example, in many European universities for advanced students to study mainly in lecture courses and, in laboratories, to practice research techniques and to review classical experiments. Their advanced experimental work began after graduation, and then mainly in research institutes which had no connection with universities. The principle of this European instruction was that students shall learn first what has been established in their science and have new research proceed from that. American students, by contrast, tend not to be as well informed about the history and organization of the achieved knowledge in their sciences but, perhaps because of their earlier start in research, to be more lively and adventuresome in experiment. There are contentious questions about which system prepares better theorists, which is better for preparing experimentalists, and whether it is better to educate for theory or experiment. Had the systems continued to be distinct, they might have provided an important educational experiment. In fact, however, the educational programs in many European countries are coming to be more like our own.

The emphasis in our graduate instruction is to prepare scientists who can conduct research and, through research, to make new contributions to knowledge. Research comes into graduate instruction at different stages of graduate study; there are variations from field to field. In some fields, graduate studies begin with formal courses, lecture or seminar courses, and research is conducted at this stage under close faculty supervision. More independent research courses are introduced later. In other fields, chemistry for example, research is part of instruction from almost the very start, so much so that the standard caution to graduate students in chemistry is that they should look around to find out what is going on and not commit themselves to one laboratory in their first year.

Graduate study is concluded with a doctoral dissertation. It is to be an original contribution to knowledge. The final degree then is awarded for a program of combined study and research, where dissertation research is independently conceived and conducted, though it is supervised by a faculty adviser and examined by a faculty committee.

The ideal combination of instruction and research occurs as a graduate student works closely with an accomplished scientist on a research project of importance. He or she will then come to a sense of the importance of different lines of research and learn the techniques, disciplines, and the adventure of research. Many graduate students have had and still have such fine experiences. In some fields, however, this ideal is no longer so often achieved. That is because of the increased scale of university research projects and because the equipment needed for some advanced research is not available in universities.

Changes in University Research: Directions

Funding for university research has increased more than ten-fold in the last thirty years. Universities have adjusted and adapted to the changes of size and complexity which have come with increased research; in turn, they have been greatly changed by them. Now, as there are prospects for still further changes in research, there will be other sorts of changes for universities. In some fields, for example, the connections between research and instruction are being changed. Other changes may lead to modifications of the structures of universities and even to changes in their purposes.

Instruction

There are mainly two causes for the changing connection between graduate instruction and research: first, the location of research equipment, and second, the large sized organization of some of the research projects in the universities.

Regarding location, universities no longer have suitable equipment for advanced experimental research in many fields. The large equipment which is needed in high energy physics, for instance, is more expensive than universities can afford. No universities have it, though most have access to it in federally funded laboratories and facilities. There are similar facilities with equipment in other fields.

Some of the federal facilities are located on or near university campuses. For the faculty and students of nearby universities, the ideal of instruction through apprenticeship in research can be continued, though it is qualified by the complexity of the equipment, of facilities, the number of scientists required both to maintain and operate it, and to plan and schedule its research programs. Education in a research facility is rarely one on one.

The faculty and students of universities which are farther away from such facilities do not have ready access to equipment; that causes a further departure from the model of instruction as apprenticeship research. Faculty and students have to travel to the facilities, and have often to be away from their own universities for extended periods of time—to ready the equipment for their experiments, to use it, and to collect and interpret their results. It often happens that a faculty member and his or her student will not even be at a facility at the same time.

These departures from the match of instruction to research are caused by the expense of the equipment needed for advanced research, the administration and operation of the facilities in which the equipment is located, and, for some faculty and students, by the need to travel, consult, and cooperate with others to define research which is fitting to the equipment and the schedules which are devised for its effective use.

There are educational advantages and disadvantages to having graduate students engaged in detached studies in government facilities. The advantages sometimes seem to outweigh the disadvantages. In many fields, not in the physical sciences alone, graduate students regularly leave their universities for research in the field, in anthropology, for example, in history, and in some of the arts and humanities, for studies in foreign history, art, literature, and culture. The troubling difference between a year in the field and research in a facility is that, in some of the sciences, where research is the largest part of graduate study, students have to be away for much of their graduate study—for so much of it that questions have begun to arise about *where* they are doing their graduate study and *with whom*.

The second qualification on the ideal is due to the size of some of the research projects which are directed by professors in universities. The ideal supposes that an individual professor has a project and that he or she works on it with a few graduate students. In these times, however, some professors direct very large projects. They have post-doctoral fellows working with them; they also employ non-faculty research scientists and technicians who are paid from project grants; research groups are engaged on their projects. A supervising professor both manages the research and engages in it—and he or she will often do more managing than research. The size of the research group, therefore, filters the association of the student and the supervisor. The association between professor and student has been so extensively qualified that questions have begun to be raised about whether

large sized projects are compatible with the instructional responsibilities of the universities, or whether they should be conducted in affiliated university or government sponsored research institutes, rather than as extensions of the research which is supposed to instruct graduate students and to bear on the instruction of undergraduates.

The changes caused by equipment requirements and the large size of research groups, however, appear immutable. For some types of research, the location of equipment, near or far from universities, has been settled by the origins of the prior parent research. For others, certain locations are coercively required for the equipment itself. It would make no sense, for instance, to place national astronomical observatories in the cities in which universities are located. Telescopes and their associated equipment have reached a stage of development where, given adequate funds, significant advances in astronomy are only possible by building the best telescopes and locating them in the places which are best for observation. The success created by doing so, nevertheless, creates problems for university astronomers, their departments, and their students, and for the universities themselves. There are comparable consequences caused by the location of other major experimental equipment.

Neither is it feasible to rail against the size of research teams. Some research questions simply dictate efforts of large scale. It is common these days to see research papers with a dozen or two dozen authors. In some fields, then, our conception of a professor working closely with a few graduate students already has had to change. What new conception we should have of graduate research instruction is not yet clear.

Support for Research and Research Careers

As the research operation in universities has grown, its drain on university resources has been reaching toward levels which are insupportable. Some of the financial strains directly affect members of the faculty. They must compete for research grants, for equipment and supplies, for stipends for their graduate students, and often for portions of their own salaries. University resources, in high proportion, must otherwise be devoted to the support of the research—for the research which is not supported by federal grants, and for a wide range of research facilities.

University funds are also used for a match, or a partial match, for a government award. Such awards are often made for equipment. It often happens that when a federal agency approves an application for research equipment, it will propose providing half the cost of the equipment and the university scientist will have to ask his or her university for the other half. There were times when the government was able to provide a large portion if not the whole cost of equipment. It does not do so now, and universities strain to provide even partial costs from their own funds. Private universities are near the limit of the resources they can provide for the support of science and research; there is only so much research they can pay for. The same is true for research in state universities, and in many of these there has been a further and very troubling development.

Many state legislatures have cut their appropriations for university research. Proposition 13, inflationary pressures, and skepticism and suspicion about research have led many legislatures to be more conservative in their allocation for research. They have also begun to ask what research is specifically in the interest of the state. Many applied research programs in state universities still receive ample support from state legislatures. Serious cuts, however, have been made by many states in the funds which were used for basic research.

The disinclination of states to support basic research indicates a serious difference in interest and a growing sense that there should be a division of responsibility in the organization and support of science. The growth of research in our universities over the last three decades has been derived mainly from federal support. But funds also have come from the endowments of private universities and the appropriations by state legislatures. The large, private universities seem intent on continuing major allocations of their resources for research. That is no longer widely in prospect for the appropriations for state universities. The Federal government thinks that basic research is in the nation's interest. Concerned for what they take to be the specific interest of their states, many state legislatures are not so willing to support it. The line has not yet been clearly drawn—but the division which some legislatures favor is that the Federal government should support what is in the national interest while the state supports what is in the interest of the state. If this line, this division, is drawn more firmly, it will affect the government's policies in supporting basic science in the university.

Finally, added to the difficulties for universities which are owed to the size, complexity, and the costs of research, there are new difficulties of another kind. They are caused by the fact that there will be fewer undergraduate and graduate students in the next two decades, and that they will not enter the sciences in the same proportion as students have entered them in the past. They are moving instead toward engineering and other professional disciplines. The projections, then the numbers, are doubly threatening.

How are the universities to maintain that large size in their science departments which is needed for vigorous research programs? How are engineering schools to enlarge their faculties when fewer baccalaureate engineers are entering the graduate schools and planning careers in research, and the schools have to compete with industry to keep their existing faculties? How are the medical schools to interest medical students and young physicians in research careers and overcome the already evident shortage of clinical researchers? How, in general, is the nation to be assured that our enormously fertile research enterprise will remain of suitable size and quality? These themes are urgent; resources are strained, universities must place themselves in as flexible and responsible a position as is possible.

Summary

University research is large sized and of high quality. It is supported by federal funds and could not be kept to its size without continuing government support. Still—crucially—university research programs are supported by the university's own tuition, its endowment, and by appropriated funds. It is unlikely that these three sources can be substantially increased. The continuation of large scale university research depends mainly on federal support; an increase in scale would depend entirely on the government. It is not clear, however, that further major increases in the scale of university research would be good for the instructional responsibilities of the universities. Some university programs are now so large that they do not allow for the associations in instruction which we used to think were ideal. Many of these programs require organizations which effectively make their principal investigators managers rather than researchers. Universities have adapted and adjusted to the conditions which have led to these changes over the more modest and traditional proportions of instruction and research. However, there are strains upon the universities now, and the prospect of decreasing numbers of students and fewer new faculty appointments raise the question whether university science and research will renew themselves in strength enough to satisfy the needs of the nation.

Federally Funded Research Facilities

Past and Present

There are many government facilities devoted to basic experimental research. Some were founded more than a century ago; most, however, were established in the last thirty years. All the facilities derive their funds from federal sources, and each is charged to carry out research in support of a particular national interest, or to provide facilities for such research. Apart from these similarities, the facilities differ markedly in their organization and administration, and in the extent to which research is conducted in them by their own staffs or by the faculty and students of user universities.

Some examples will illustrate the differences among the facilities:

Agricultural experiment stations and Sea Grant College programs are administered by individual universities and function like other research units of their host institutions.

Regional instrumentation centers and some national laboratories, the Stanford Linear Accelerator Center, for example, are operated by individual universities but are available to users from other research communities.

Some facilities, like the Los Alamos Scientific Laboratory, Lincoln Laboratory, and the Jet Propulsion Laboratory, are managed by individual universities, combine both research and development, and are open to investigators from other institutions.

Others, like Brookhaven National Laboratory and Oak Ridge National Laboratory, have similar functions but are operated by consortia of universities.

Agencies of the Federal government fund and operate a variety of research facilities; for example, the Naval Research Laboratory, the National Bureau of Standards, and the intramural research programs of the National Institutes of Health and the hospitals of the Veterans Administration.

Finally, several federally funded, nonprofit corporations have been established in support of federal missions—the Rand and MITRE Corporations, for example.

The associations between these types of federally funded facilities and university research and researchers range from intimate to distant. They depend on where the facilities are, who administers them, what their research programs are, and how large and how good a staff they have. When the facilities are physically or organizationally close to universities, their programs are usually defined in consultation with university scientists. They are then conducted by the staff, some of whom may have part-time appointments in the universities. In turn, university faculty may have part-time appointments in the facilities and their graduate students may serve in them as research assistants.

By contrast to the facilities which have their own research programs, other facilities are open to wide use by university scientists. The facilities provide equipment. University scientists adapt and use it on schedules which are established by the facility to take account of the importance of the proposed research, the time and expense required for its conduct, and the number of persons who apply for instrument time. It is not unusual in some fields to wait many months or even a year or more for the use of experimental equipment. When equipment is being planned and constructed, experiments are usually projected years ahead.

In many fields, crucial parts of forefront research can only be conducted in the federal facilities. This is true of some parts of high energy physics, for example, and for some parts of astronomy, atmospheric science, biology, and medicine. Scientists can think about issues anywhere; the same is true for details of theory and experimental design. But experiments have to be conducted with the equipment at the facilities—and at some facilities, university scientists find congenial associates. There is a strong scholarly atmosphere in some of them. It comes about naturally, and is often supported by formal lectures and by colloquia and short seminars which present the newest questions in the facility's fields. Facilities do not offer formal instruction. But a good deal of learning takes place in them, and some of it is credited to the programs of the graduate students who are visiting in the facilities and conducting their research there.

Prospects

The Commission believes that the federal research facilities will become increasingly important in our national research enterprise, and that more and larger facilities will be founded in the years ahead. There is an ample

basis for these predictions. The need for special research equipment, too complex or expensive for any one university to construct, is growing, even in fields where experimental facilities already exist. The need is also appearing in fields where it had not been shown before, in the social sciences, for example, where major equipment for collecting, storing, accessing, and processing huge stores of data on nationwide samples of individuals and groups is becoming more essential for research. Then too, as economic stringencies increase, universities are more often calling for the use of the facilities. The number of research and development programs requiring massive team efforts is increasing, and these may be more appropriate to federal facilities than to university research organizations. The same is true for interdisciplinary research. Many researchers believe that it can be done more readily and more completely in the federal facilities than in discipline-divided university departments.

Given the prediction that there will be more and larger federally funded research facilities and that these will have an even more prominent place in the nation's organization of research, the Commission sees that there will be new questions in the changing associations of the facilities and the universities. These should be anticipated and discussed.

Questions, Problems

The federal research facilities will continue to be supported by the Federal government. The scale of programs in some of them will be increased; others may be reduced, redirected, or even phased out. Additional new facilities are sure to be founded, and not only in the physical and biological sciences. It seems clear that in economics, government, history, and sociology, data banks and equipment more extensive than universities can provide will be needed in the future. Within the decade, it is likely that there will be research centers in these and perhaps even other of the social sciences.

There will, therefore, be issues of importance in planning the development of new facilities, and in fitting the research of the facilities with the research which is being conducted and projected in the universities. These will not be without difficulty—because the environments of the universities and some of the facilities will be different, and because there are some disturbing differences in the quality of university and facility scientists and in the quality of their projects. In overlapping research areas, it will not always be easy to define what sort of research should be done in the universities and what sort is appropriate for the facilities. Nor will we easily establish companionable, collaborative relationships between facility staffs and university science faculties. While the need, use, and funding for federal facilities will increase, the Commission cautions that their association with universities be developed with thoughtful care, taking advantage of their differences, and not allowing the differences to lead to the pernicious distinction in which the facilities become the favored "haves" of research, while the universities feel themselves becoming the neglected "have-nots."

In general, the divisions of research which are appropriate to the universities and the facilities are suggested by the factors which led to the founding of the facilities. Most of them were founded to conduct important research which is beyond the resources of or inappropriate for the universities. Research is always limited by resources; there are always things we think it would be good to try but which our resources do not enable us to do. In certain areas, for certain kinds of research, the major investment of federal resources should be in the facilities; for others, the investment is made properly in the universities. The suggested divisions between university and facility research turns on resources—but resources in a broad sense: scale, projected length and direction of proposed research, the kind and amount of equipment required, the number and quality of scientists needed for the research, and the kinds of research which are important in the instruction of the next generation of scientists.

Usually, when research is new and its scale is small, individuals or groups of investigators in universities are quick to make singular advances and are able readily to change research direction. When basic principles have been established, and sizable and long programs which require large and expensive equipment are projected, national or regional facilities are the best places for research. They are perhaps also best for the studies which lead to the application of research results. In some fields, lines of experimental research tend to be established in universities and then to go from universities to facilities, not the other way around. Questions of theory should go readily in both directions.

Universities, then, are likely to be the home of the research which, on recent classification, is of relatively modest scale, which does not require many million dollar pieces of equipment, which is open to scientifically motivated shifts of direction and which is of instructional importance. Facilities are likely to be the home of the larger, equipment freighted, and mission directed research. Some such division between universities and the

facilities will be both appropriate to the universities (some of which have been strained and distracted by trying to establish research facilities of very large scale) and good for the advancement of science—provided that the quality of research in both the universities and the facilities is strong.

The quality of university science is assessed in the appointment and promotion processes of the universities and in the competitions in which university scientists apply for research awards. The standing of persons in these processes distinguishes the major research universities from those whose capacity in research is not so strong. There are comparable rankings of the facilities. Some of them are widely acknowledged to be excellent. The common opinion in scientific circles is that other facilities are only routine, and that they have not been able to attract many exceptional people or to keep them on their staffs. Issues about the quality of research facilities are of major scientific importance. This quality is also "politically" important—for it would be intolerable if federal funding for good research in universities were reduced while facility budgets were increased for research which is not as good as the research conducted in universities.

It has been fortunate—and the consequence was probably provisioned—that the competition between the universities and the government research facilities has not been more contentious. There is good cooperation between them when the facilities provide an accessible extension for the instruction and research which is conducted in the universities and when university faculty contribute to the planning and conduct of facility research. The contention between them, in prospect and in fact, occurs over the accessibility of facility equipment, the assessment by each of the importance of the other's projects, and their general competition for federal funding. These contentions could become severe. The adjustments, the accommodations, and the thoughtful policy that will reduce them have to be planned with care.

There is some important research which cannot be conducted in universities. There is a current which is taking still other research into proposed facilities. It would be a mistake to think that there will be a tidal move of research away from universities. Whatever the mix of the universities and the facilities in the future, it should not be the case that the research universities are assigned the generation of theory and that facilities are directed to construct experiments. However, the generation of new ideas should be especially considered in policies about portioning resources and responsibilities to both the universities and the facilities.

Summary

In some fields of science, the major federal facilities are the places where forefront research is being done and where for even other fields it is likely to be done in the future. The research staffs of some but not all of the facilities are excellent and many young scientists on the facility staffs anticipate continuing their careers in them. They are not turning or returning to university teaching positions.

Compared with universities, support for research in the federal facilities is simpler and more assured. The facilities have, of course, to apply for funds, but they do so in the large and there is less jeopardy for individual researchers than there is in the universities. University researchers compete individually for grants. Because of the increased number of high quality scientists, the competitions have become intense. It is common now for projects to be approved by peers and panels and yet not to be funded. This usually means that the researchers in universities are not able to continue their projected work, or not to do as much of it as they would like. The loss of a grant breeds the further jeopardy that the work they are able to do may not lead to projects which will receive future support. By contrast, in the research facilities, if individual researchers are not able to do the projects they propose, they commonly undertake another part of the facility's general research program.

Research facilities are more simply purposed than universities. Faculty members in universities have many kinds of responsibilities; many of them note that they are not able to do enough research. Where the programs for research in the facilities is strongly assured, the programs in universities are assured, but not as strongly or continuously; and in the universities, research is affiliated with other responsibilities. Research in universities might be improved if its funding were patterned more on the kinds of support provided for the facilities. It would perhaps also be of use if the excellent research facilities were to assume some of the responsibilities which are entrusted to the universities. The research system of the nation might be enhanced if there were trades or transfers between them.

Notes Toward the Formulation of an Agenda

Most basic research is done in universities by individual investigators and by small and large groups of faculty, students, and employed scientists and technicians. An increasing amount of research—in some fields, the most advanced research—is conducted in federally supported research facilities. Research in both sorts of institutions is regularly reviewed; there are strong and, for the most part, good associations between them, and the quality of university and facility science is generally high.

Do the organization, quality, and resources of university and facility science assure us against the apprehensions which have been expressed about the prospects for very high quality in research in the future? The Commission does not think so, because some of the apprehensions have been expressed both by spokesmen for the universities and for the government facilities. Some of their dark assessments are unrealistic and should be set aside. Neither the universities nor the facilities can be enabled to do all they might want to do. But it would be unwise merely to shrug at all of them. While it is difficult to shape the apprehensions into problems, the first step in that direction is to look at the kinds of things we want from research and to ask, in general, what measure will give us strong assurance of getting them.

We want three things. The first is a large group of people who can conceive and conduct research, well schooled but imaginative, resourceful and dedicated persons, women as well as men, and persons from the minorities which in years past were not so often able to prepare for careers in research. Secondly, we also want incisive basic research in all the major fields, research which, it is hoped, also will be applicable in the near or foreseeable future. Finally, we want resources for our scientists which will enable them to construct and conduct science of the highest quality.

How, in general, are we going about getting the three sorts of things we want? Is there anything so seriously unsatisfactory in what we are doing that it should make for apprehension? If so, what changes can and should be made? The answers to some of these questions are ready information. Answers to others, and reasonable consensus about the answers, will have to be established. The Commission believes that these are issues for further and future discussion.

People

We look to universities to provide well instructed young scientists who can participate in basic research, either as faculty members or members of the staffs of facilities or as researchers in industry. We also expect the universities to provide enough young scientists so that the research which should be done can proceed on well paced schedules. These young people should be learned and disciplined, and imaginative enough to excite and sustain themselves through long and effective careers.

Three conditions seriously qualify our confidence in these hopes or expectations.

First, there is the so-called "young investigator" problem. There are now fewer young people preparing for careers in basic science—because graduate study in science is not as financially feasible as it used to be, and because there are reduced opportunities for careers as scientists in universities and not yet very many opportunities in the federal facilities. Meanwhile, careers in business and the professions have come to seem more challenging and financially, and perhaps even socially, more rewarding.

The problem is serious, more so for some universities than for others. Some of its conditions have been studied, and considered recommendations for changing them have been made. Several committees, for example, have called on the Federal government to provide more graduate fellowships in science and engineering. The Sloan Commission has suggested that there be graded and renewable post-doctoral fellowships, which would tide over a reasonable number of able young scientists until there are increased opportunities for appointment to university faculties. In a searching and balanced report, the Bock Committee has recommended that the Federal government help to hasten the rate at which young scientists are to be appointed to universities.

All of these proposals deserve careful discussion. They are concerned with the number of scientists and the rate at which suitable numbers of them will be appointed to research positions. Each, however, looks to the eventual placement of scientists in university facilities. But it is an unsettled question whether the universities can accommodate more scientists on their faculties, and whether they can and should undertake more sizable research projects on which large numbers of non-faculty scientists might be employed. It is also important to ask

whether government research facilities will or can or should be so substantially increased in size or number that they will provide more opportunities for employment, and whether industry will find it advantageous to create more openings for basic scientists. If more positions are to be opened in one or another of these sorts of institutions, there should be discussion as well of how the positions might be rendered attractive and rewarding enough to invite young people to consider research in science as a career. Many talented young people do not find it so now.

The second qualifying condition relates to the education of scientists. We should look again, appreciatively and critically, at our expectation that universities shall provide the whole educational preparation of young scientists. Universities have combined graduate instruction and research. For more than a century we have approved of that philosophy. In some fields, however, advanced research is moving away from the universities. University faculties and students move after it, changing not only the locale of their instruction and research, but also effectively making the staffs of the facilities instructors as well. Our policy of coupling instruction and research has meant that all instruction leading to advanced degrees has been provided by and in the universities. The university community should recognize that there will be recommendations to loosen the integration of the two and, in some fields, to offer graduate instruction, under other auspices.

The third qualifying condition relates to those persons already established in careers in science. All of our research institutions are troubled to note that some scientists do not sustain their interest in research and may even fail to keep current in their fields. Some of the apprehensions about the vitality of science have been expressed as concerns to have more young people enter research, even though it has been established that older scientists are not less original or productive than younger ones. The issue, however, is not simply a matter of youth or age. It is about sustenance in careers; in every profession some people lag behind or fall away. There are no doubt many reasons why they do. The leading ones are an inappropriate initial choice of careers, lack of suitable incentives or rewards, and preoccupations for too long with unsuitably defined projects.

There has not been enough thought given to the moods and other changes in the careers of researchers. In universities, there are stages of promotion and securities provided by tenure; in research facilities, there are ranks and grades. Even so, as a complement to the concerns expressed to have young people enter research, we should consider what more can be done to freshen the lives and interests of established researchers, to see that their work is recognized, and that they are not distracted because of insufficient compensation.

Good associations between the universities and research facilities could be the basis for useful exchanges of persons and positions, and such exchanges might also be developed with industry. The Commission does not specifically urge that a program of exchanges be established. Neither does it recommend specific measures for mixing the young and the old, nor specific mechanisms for allowing changes of research interests and responsibilities. We believe, however, that it will be important in further reflections to think carefully how, over their careers, researchers can be encouraged and sustained in vivid professional lives.

Basic Research

As for the incisiveness, breadth, and applicability of research—these are matters of the kinds and characters of intelligence, critical, speculative, and practical—these are shaped by our educations and the communities in which intelligence is solicited and practiced. There has been too little thought on these matters, as if on points like these we express our highest aspirations but do not think how they can be achieved.

Efforts were made some years ago by ranking scientists to improve education in science in the schools. These efforts were not markedly successful, or not so at once. Thus, we should wonder how sensible we were to think that minds and motivations could have been made so readily. Fewer such efforts have been made since then.

The communion between scientists and those who are professionally interested in science education is not good enough. In universities, these persons are normally in different departments. Scientists often think that only "failed scientists" go into science education or teach science in the schools. It is also common that scientists then complain about the preparations which students have received in the primary and secondary schools, and about how little students know when they enter college.

The sturdy attitude of many university scientists is that students will only learn science when they do research. This attitude too often leads them to neglect the understanding of persons who do not plan on being scientists but whose own later attitudes, as citizens and policy makers, affect support for science and research. It also leads their students to be so occupied with science that they come to study little else, with what restraints upon their imaginations and appreciations no one seems to know. Given the "do research" attitude that is common in

instruction in the sciences, it is not surprising that the education of so many persons in the sciences tends to training and routine and that the persons who are not in science should find it mysterious and valued chiefly for its practical results.

Reflections on the state and prospects of science and on what the universities and government might do to improve them are issues about the quality, suppleness, imagination, and critical cast of scientific minds. Fine minds may cope with arrangements that are not excellent; excellent facilities and arrangements may not make for fine minds. We have, therefore, to reconsider carefully ~~how~~ scientists are to be educated, and also how those who are not scientists are to be educated in science and informed about it. There is properly a concern about the number of scientists we are thought to need. But, as noted earlier, there is no ready correlation between the number of scientists and their quality. Preoccupations with numbers tend to presuppose and then to neglect issues of quality. The Commission believes that the issues of numbers and quality should be balanced. Perhaps to balance them, they should be put the other way around so that more concern about the quality of scientific preparation and research will lend larger numbers of able persons to make their careers in science. These issues are the most important of the long range issues about scientific personnel.

Resources

Finally, in connection with resources, the common complaint of scientists in the universities and government facilities is that they do not have resources enough. There is no doubt that the equipment problem is severe. Ten years ago there were very large federal appropriations for equipment in the universities. Funds have been reduced since then and university scientists are increasingly troubled that much of the equipment they received from the government is now old, in need of repair and modification, and would even then not be altogether suitable to the new research which should be done. Universities do not have the resources to repair and replace this equipment. They must look to the Federal government for additional support.

The universities and the federal facilities are the major centers for basic research. Both have to be sustained and have their effectiveness assured. Now, in some fields, universities are the only centers for continuing research. In others, they have the important competence that they can, very quickly, inaugurate new lines of inquiry. The initiatives of individual researchers are of irreplaceable value. Facilities, on the other hand, because of the enormous costs of the equipment, have to devise long range research missions; particular new projects have to be nested within the long range ones. Facilities are not so readily able to follow new scents and leads.

The themes—long range, short range, and the ability to change direction—are notes in the comprehensive view of the versatility of our research resources. The Commission believes that they have been neglected and that they should be considered in response to our apprehensions. In our concern for the prospects for research, we have not suitably noted the variations and paces of research. The main concern of universities has been with science in the long run, and yet the universities have also been the home of good fortune in research, serendipity, and novel directions. The initial interest of the Federal government in research was an expectation for short term results. Now anomalously, government supported facilities are directed by longer range objectives. There has to be more deliberate sorting of responsibilities, whether of long or short term, and the Commission believes that such issues too should be among the items on an agenda for further discussions.

Items for an Agenda

The National Commission on Research has published four other reports. Their character is very different from this one. The major differences are that the other reports are more analytical than this one and that they feature conclusions and definite and directed recommendations, to the universities, the Congress, to the federal agencies, the scientific community, and to industry. By contrast, this report is a set of notes about research in universities and federal facilities, and it has few conclusions and no recommendations. It is haunted by the apprehensions which have been expressed about the prospect that basic research and science in our country will not continue the momentum they have had, that the quality of our science will lessen, and that there will, therefore, be damaging consequences for our industry and economy, our diplomacy and national standing.

The Commission has tried to locate and assess the bases for these apprehensions. Several of them are clear, in the facts about the numbers of students there will be, the numbers of new faculty appointments that will be made, and the levels of funding that will be needed. Still, the apprehensions themselves are elusive. We are not convinced that anyone has formulated them as problems which can be solved in a simple way. Our view is that they arise out of conditions of change and of uncertain direction and consequence, and that they do not render themselves readily as problems. Indeed, the reservations the Commission has about several of the manpower projections and the recommendations based on them is that they suppose that only the numbers of persons will change and that things otherwise will remain unchanged. Our view instead is that many things are changing, and that we should, therefore, locate the arenas of change and invite discussion of how the changes might be directed, so as to improve the consequences projected because of reduced research personnel in universities, and to improve other conditions as well.

The Commission believes that the most basic changes are occurring in science itself and in the institutions in which science is taught and research is conducted. Part of the growing apprehension is that many of us feel ourselves on the verge of major new scientific results and that we do not know what their effects will be. This is true especially in high energy physics and biology. Examples may be seen where the public has become familiar with results from bacteriology, from computer science, or from nuclear physics, but is uncertain now what science will do next and whether or not it will be good and useful. It is also as if our apprehensions were mated to "all of our problems" and to their magnitude. Mistakenly or not, we have come to think that the solution of all of our problems will come from science and research—and we have become either uncertain whether that is so, or impatient for the solutions, or both. We are not as a nation notable for our patience.

The Commission has not studied the poise of major scientific questions or the pace at which they are being resolved. We have been more concerned with the other major conditions of change and uncertainty which we think are also a cause of our apprehensions. These are the changes in universities and in the government research facilities, the institutions in which science is taught and in which basic research is conducted. Universities do both; the sole mission of the facilities is research. Yet, in their larger projects, universities are becoming more like research facilities, and because many university faculty and students visit in and conduct their research in government facilities, the facilities are becoming more like graduate universities. We think that these changes, along with the strains and limitations of conducting research in both these sorts of institutions, account for the institutional expressions of our apprehensions. The Commission believes that further discussion of these conditions would contribute to directing the changes which are occurring now without suitable authority from more comprehensive thought.

The Commission, therefore, completes its exposition by proposing items which might be on the agenda of university, foundation, and government committees, or on the agenda of the sort of Forum which the Commission already has proposed to consider issues in the association of the government and the universities for the conduct of research. The following are among the themes which we think should be discussed:

1. Are the universities, is the government (as having a general interest in science) satisfied with the ways in which young people are introduced to science in the elementary and secondary schools? If they are dissatisfied, what is their dissatisfaction, and what do they propose to do about it?

2. Are the universities satisfied with the ways in which college students are introduced to science, the students who will major in science, and also those who are not looking forward to scientific careers? Since broad public attitudes, whatever their understanding or misunderstanding, have their basis partly in our educations, if the universities are dissatisfied with those attitudes and with the introductions which they provide for their students, what improvements do they propose to make?

3. Are the universities, is the government, and are the facilities concerned about the numbers of well prepared scientists we will need at the start of the next century? Are they sure that they will have or can create places for the numbers of scientists we will need?

4. Are the universities and the facilities satisfied that they have devised effective means to assure access to scientific careers for persons from all sectors of society, including minorities, handicapped, and women? Is the government satisfied that it applies appropriate and effective mechanisms to enforce Constitutional and statutory rights for equal opportunity? Is society satisfied with government performance in these responsibilities? Are these access and equality questions based on a suitable understanding of the roles and responsibilities of governmental and academic institutions and of individuals?

5. Are the universities satisfied, is the government satisfied, that it is good for universities to undertake very large organized research projects which employ non-faculty scientists and which require faculty members to reduce their instruction and research and to serve as research managers?

6. What measures can the universities and the federal facilities make to improve the research which they sponsor and conduct? What, if anything, can they do to improve the effectiveness of their research faculties and staffs, the circumstances under which their research is conducted, the procedures by which their research is administered, and the understandings their constituents have of their instructional and research programs?

7. Are the universities and the government satisfied that a judicious division has been made between the research which is properly conducted in the universities and the research which is suitable to facilities? Are there discussions between them about the division of research, about the needs for further facilities, about their most appropriate location and administration, and about the duration and paces of the research programs they sponsor and conduct?

8. Are the universities settled that the universities shall provide the whole formal education of the persons who intend to make careers in research, or are they open to experiment? Have the universities and the government considered the consequences of offering advanced instruction in some fields in federally funded research facilities, and perhaps even having the facilities become the formal authorities for the award of the Ph.D. degree? Are all other institutions satisfied with the principle that instruction shall be provided by university faculties even while advanced research by some students is conducted in government facilities?

9. Are the universities and the government satisfied that they have done all they can to assure that the laboratories of their scientists are well equipped?

10. Are the universities and is the government satisfied that their procedures for administering research are as unobtrusive and non-interfering as possible?

11. Have the universities and the government given attentive thought to the changes which occur in the research lives of the scientists and to their effects on their morale and productivity?

12. Are the universities and the government satisfied that they have devised effective means of making accessible to industry and to the public at large the results of the research they sponsor?

13. Is the government, and are the universities and industry satisfied that they understand their mutual interest in having excellent research conducted, and are they satisfied that they cooperate suitably in defining, supporting, and conducting research?

It is within the context of issues of these broad sorts that the Commission believes our apprehensions about research personnel for the future will find their most discerning formulations and resolutions. The Commission also believes that many of the issues are urgent, that problems are upon us, and that their solutions, even if we saw them soon, would take precious time to effect. The Commission, therefore, urges that the issues be discussed at once, by the President, by Congress, by federal agencies, by universities and their associations, by industry, by others interested in science research and education, and by persons who might serve in the Forum whose founding the Commission recommended in earlier reports.

Appendix I: Federally Funded Research and Development Centers Administered by Universities

Center and Location	Federal Expenditures, FY 78 (in millions of dollars)	Principal Support Agency	Administered By
Ames Laboratory (Iowa)	14.1	Department of Energy	Iowa State University
Argonne National Laboratory (Illinois)	220.7	Department of Energy	University of Chicago and Argonne Universities Association
Brookhaven National Laboratory (New York)	116.7	Department of Energy	Associated Universities, Inc.
Center for Naval Analyses (Virginia)	9.6	Department of Defense	University of Rochester
Cerro Tololo Inter-American Observatory (New Mexico)	3.9	National Science Foundation	Association of Universities for Research in Astronomy
Fermi National Accelerator Laboratory (Illinois)	86.4	Department of Energy	University Research Association
Jet Propulsion Laboratory (California)	224.8	National Aeronautics and Space Administration	California Institute of Technology
Kitt Peak National Observatory (Arizona)	9.7	National Science Foundation	Association of Universities for Research in Astronomy
Lawrence Berkeley Laboratory (California)	99.0	Department of Energy	University of California
Lawrence Livermore Laboratory (California)	306.4	Department of Energy	University of California
Lincoln Laboratory (Massachusetts)	99.6	Department of Defense	Massachusetts Institute of Technology
Los Alamos Scientific Laboratory (New Mexico)	294.5	Department of Energy	University of California
National Astronomy Ionospheric Center (Puerto Rico)	5.6	National Science Foundation	Cornell University
National Center for Atmospheric Research (Colorado)	32.7	National Science Foundation	University Corporation for Atmospheric Research
National Radio Astronomy Observatory (West Virginia)	22.1	National Science Foundation	Associated Universities, Inc.
Oak Ridge Associated Universities (Tennessee)	5.6	Department of Energy	Oak Ridge Associated Universities
Plasma Physics Laboratory (New Jersey)	41.6	Department of Energy	Princeton University
Sacramento Peak Observatory (New Mexico)	1.8	National Science Foundation	Association of Universities for Research in Astronomy
Space Radiation Effects Laboratory (Virginia)	0.6	National Science Foundation	College of William and Mary
Stanford Linear Accelerator Center (California)	80.0	Department of Energy	Stanford University
TOTAL	1,675.5		

Source: National Science Foundation

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Appendix III: Sources

The Commission is indebted to the many persons who have provided information and advice, and it wishes to acknowledge its appreciation for their efforts. Invited expert witnesses have testified on the issues within the Commission's purview at its monthly meetings; open hearings have been held on five university campuses; subcommittees have met with individuals and groups from the Federal government; and members and staff have attended or made presentations at meetings and hearings convened by educational associations, government agencies, and Congress.

Witnesses and advisers. The following individuals presented views and gave assistance in the development of this document. The Commission wishes to emphasize that the views in this document are its own and not necessarily those of the listed individuals.

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Mary Chezmar, National Science Foundation
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William F. Raub, National Institutes of Health
Jerold Roschwalb, National Association of State
Universities and Land-Grant Colleges
Jack Sanderson, National Science Foundation
Helen Schroeder, National Institutes of Health
I. M. Singer, Committee on Science and Public Policy,
National Academy of Sciences
Edwin Young, University of Wisconsin

Agency Liaison: These persons have been appointed by their agencies:

Salvatore Cianci, Alcohol, Drug Abuse, and Mental Health Administration
George P. Millburn, Department of Defense
Richard E. Stephens, Department of Energy
Osmund Fundingsland, General Accounting Office
Walton Francis, Department of Health, Education, and Welfare
James R. Lawson, National Aeronautics and Space Administration
William F. Raub, National Institutes of Health
Jack Sanderson, National Science Foundation
Eliot R. Cutler, Office of Management and Budget
Philip M. Smith, Office of Science and Technology Policy

Open Hearings. Over seventy persons testified before the Commission during hearings at the national conference of the American Association for the Advancement of Science and on the campuses of the University of Alabama, Birmingham; California Institute of Technology; Stanford University; the University of Wisconsin, Madison; and the University of Utah with the Inter-Mountain University Research Association. A number of these speakers presented views on research personnel in addition to other topics under consideration by the Commission.